When it was discovered that the development of the embryo sac in *Lilium Henryi* differs from the "lily type," the preparations of lily material used for class work in the Botany Department at the University of Wisconsin were examined. These slides include material from three species, *L. speciosum* Thunb., *L. philadelphicum* Linn. and *L. longiflorum* Thunb. var. *eximium*, Nichols (*L. Harrisii*, Carr.). The history of embryo-sac development in this material was found to be similar to that here described for *L. Henryi.*

* Papers from the Department of Botany and the Department of Genetics (No. 169), Agricultural Experiment Station, University of Wisconsin. Published with the approval of the Director of the Station.

[1] Sargant, E., *Annals Bot.*, **10**, 445–477 (1896).

[2] Mottier, D. M., *Jahr. Wiss. Bot.*, **31**, 125–158 (1898).

[3] Bambacioni, V., *Rend. Acc. Lincei Roma, Cl. Fis. Mat. Mat.*, Ser. **6.6**, 544–546 (1928).

[4] Bambacioni, V., *Annali Bot.*, **18**, 7–37 (1930).

[5] Bambacioni, V., and Giombini, A., *Ibid.*, **18**, 373–386 (1930).

[6] Bambacioni-Mezzetti, V., *Ibid.*, **19**, 365–382 (1932).

THE ULTRA-VIOLET ABSORPTION SPECTRUM OF CARBON SUBOXIDE GAS

BY RICHARD M. BADGER AND ROBERT C. BARTON

GATES CHEMICAL LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA

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The carbon suboxide used in this investigation was prepared by the diacetyl tartaric anhydride method,[1] and was kindly supplied by Dr. W. E. Vaughn of this laboratory. The material was purified by four vacuum distillations and may have contained a trace of acetic acid as impurity which, however, would not have been disturbing in the region investigated.

The carbon suboxide gas was contained in a quartz absorption cell 15 cm. in length, provided with plane windows and a side arm containing an excess of the material in liquid form. By controlling the temperature of the latter the gas pressure in the cell could be regulated. The absorption cell itself was kept at room temperature, which was about 21°C. The carbon suboxide apparently kept well if sealed in perfectly clean quartz vessels, especially if maintained at low temperatures, but after long exposure to ultra-violet radiation a white deposit collected on the windows of the cell. This was probably a polymerized form of the suboxide and it quickly changed over to a reddish orange form if gently heated.

The light source used was a hydrogen discharge tube of special design and the spectrograph was a large size Bausch and Lomb instrument of the Littrow type which gave a dispersion of about 4 Å per mm. at λ 3000. The spectrograms were taken on Eastman 40 plates. The wave-lengths were determined by comparison with the iron spectrum and with a few mercury

TABLE 1

ULTRA-VIOLET ABSORPTION MAXIMA OF CARBON SUBOXIDE

REGION		λ	ν	δν
	a	3197.9	31261	
1.	b	95.6	284	
	c	95.6	300	
	a	80.5	432	
2.	b	76.4	473	
	c	71.8	518	
	d	66.3	568	
	a	56.9	668	
3.	b	51.9	718	
	c	46.5	772	
	a	37.8	860	
4.	b	**30.3**	**937**	
	c	20.2	32040	
	a	13.9	105	
	b (?)	12.5	119	240
5.	c (?)	10.6	139	
	d	09.8	147	
	e	**06.9**	**177**	
	f	05.3	194	218
6.		**3086.0**	**395**	224
	a	**64.8**	**619**	
	b	63.3	635	
7.	c	61.8	650	
	d	60.4	666	
	a	49.9	778	
	b	48.2	796	244
	c	46.9	811	
	d	45.9	821	
8.	e	44.9	832	
	f	44.0	841	
	g	43.2	849	
	h	**42.0**	**863**	
	i	40.3	882	

REGION		λ	ν	δν
	a	3021.3	33089	238
9.	b	**20.2**	**101**	
	c	18.4	120	
	d	17.1	135	
	a	12.7	183	
	b	10.9	203	219
10.	c	09.2	218	
	d	07.2	244	
	e	**00.2**	**320**	
	f	2998.8	370	228
11.		**79.9**	**548**	
	a	62.0	751	233
12.	b	**59.4**	**781**	
	a	44.5	952	244
13.	b	39.8	34006	
	c	**38.2**	**025**	
14.		**21.7**	**217**	192
15.	a	07.0	390	
	b	01.1	460	
16.		**2887.9**	**617**	254
17.		**65.5**	**863**	193
18.		**51.7**	**35056**	

lines which were faintly present in the spectrum of the discharge tube.

Carbon suboxide was found to have a relatively strong absorption in a region the limits of which depend on the gas pressure or path length, but which may be given roughly as λ 3200 and λ 2500. The absorption consisted both of discrete bands which set in at about λ 3200 and could be followed to λ 3050, and a continuum overlying the bands and extending considerably to the short wave side of λ 2537 with a maximum at about λ 2600. Owing to the great variation of absorption with wave-length only from five to seven bands are distinguishable on any given spectrogram, since further bands on the long wave side are too faint to appear and on the short wave side are masked by the strong continuum. By taking several exposures with different gas pressures eighteen bands, or regions of absorption maxima were obtained with sufficient intensity to measure.

The results of the investigation are best shown in figure 1 in which are reproduced microphotometer curves of spectrograms taken at five different gas pressures. The exact pressures are unknown but they are the vapor pressures of the liquid at the temperatures indicated on the curves. The absorption maxima which were measured are indicated in the figure and the corresponding wave-lengths and frequencies are given in table 1. Some

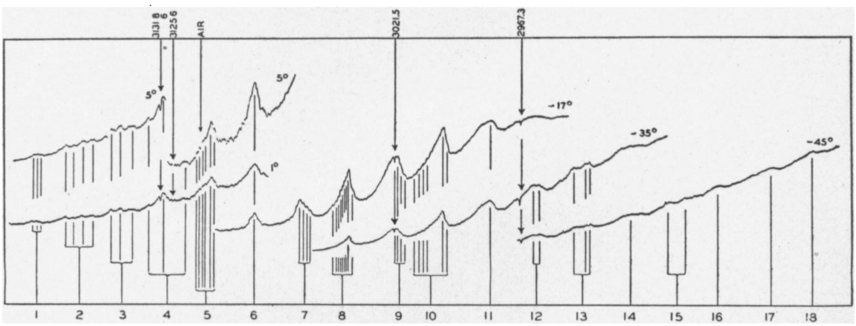

FIGURE 1

Absorption maxima in the ultra-violet spectrum of carbon suboxide gas.

mercury lines which appeared weakly in the spectrum of the discharge tube are indicated and it should be noted that on one of the plates there are a few weak air lines between the bands designated as 4 and 5, which appear as minima on the photometer curve. The continuous spectrum of the discharge was otherwise free from impurities.

Most of the bands show some evidence of complexity which can hardly be a rotational structure in the ordinary sense owing to the large moment of inertia of the molecule. Electron diffraction experiments on carbon suboxide[2] have yielded for the C—C distance 1.30 Å, and for the C—O distance 1.20 Å, and if the molecular is linear, as seems most probable, the moment of inertia perpendicular to the figure axis should be about 397×10^{-40}. The separation of the rotation lines should accordingly be about 0.14 cm.$^{-1}$, or 0.013 Å, which could not have been resolved by the instrument at our disposal.

Most of the absorption maxima seem to belong to a band progression with a spacing which averages about 223 frequency units, though on the long wave side it appears that there may be some additional bands. The magnitude of this spacing indicates that we have to do with one of the transverse or "deformation" oscillations of the molecule, and the complexity of the bands is evidently due to the existence of several vibrational levels having nearly the same energy. In the case of the ideal linear molecule with Hooke's law binding the energy levels corresponding to the transverse vibrations are degenerate, but in the actual molecule this degeneracy is of course at least partly removed and there will be several transitions which will give rise to bands in nearly the same position in the spectrum. A somewhat similar complexity of structure has been observed in the ultraviolet bands of cyanogen.[3]

[1] Hurd and Pilgrim, *J. Am. Chem. Soc.*, **55**, 757 (1933).

[2] L. O. Brockway and L. Pauling, *Proc. Nat. Acad. Sci.*, **19**, 860 (1933).

[3] Sho-Chow Woo and Richard M. Badger, *Phys. Rev.*, **39** (1932).

EFFECT OF INHOMOGENEITY ON COSMOLOGICAL MODELS

BY RICHARD C. TOLMAN

NORMAN BRIDGE LABORATORY OF PHYSICS, CALIFORNIA INSTITUTE OF TECHNOLOGY

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1. *Introduction.*—In the application of relativistic mechanics and relativistic thermodynamics to cosmology, it has been usual to consider homogeneous models of the universe, filled with an idealized fluid, which at any given time has the same properties throughout the whole of its spatial extent. This procedure has a certain heuristic justification on account of the greater mathematical simplicity of homogeneous as compared with non-homogeneous models, and has a measure of observational justification on account of the approximate uniformity in the large scale distribution of extra-galactic nebulae, which is found out to the some 10^8 light-years which the Mount Wilson 100-inch telescope has been able to penetrate. Nevertheless, it is evident that some preponderating tendency for inhomogeneities to disappear with time would have to be demonstrated, before such models could be used with confidence to obtain extrapolated conclusions as to the behavior of the universe in very distant regions or over exceedingly long periods of time.

It is the object of the present note to contribute to our knowledge of the effects of inhomogeneity on the theoretical behavior of cosmological models. For the immediate purposes of this investigation we shall confine our attention to very simple models composed of dust particles (nebulae) which exert negligible pressure and which are distributed non-uniformly